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WO 96/04722 A2

(58) Field of Search
UK CL (Edition N) H4L LDH LDSJ
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ONLINE: WPI

(54) Channel Allocation in a Cellular Radio Network

(57) A frequency allocation system for a cellular radio network of the type providing both frequency hopping and non hopping channels in which allocation of channels is performed on the basis of the quality of transmission of a call. This permits a frequency hopping channel to be used where the likelihood of interference is highest, substantially reducing the average interference level of calls.

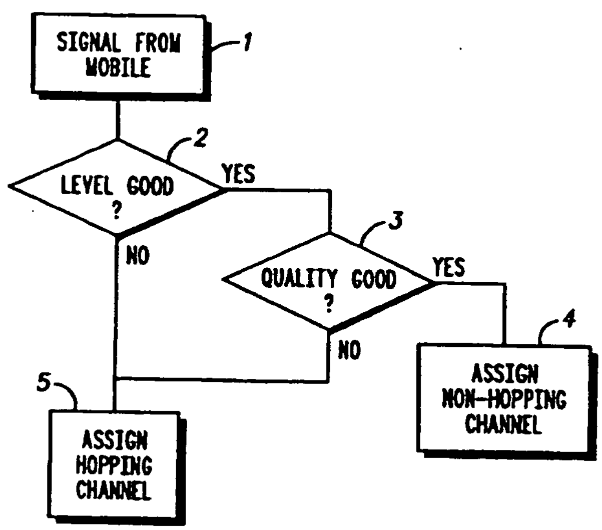

FIG.6A

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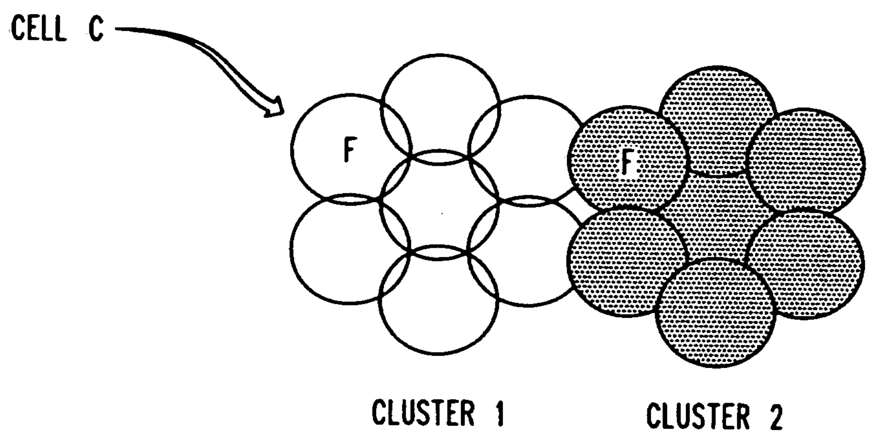

CELL C
F
F
CLUSTER 1
CLUSTER 2

FIG.1

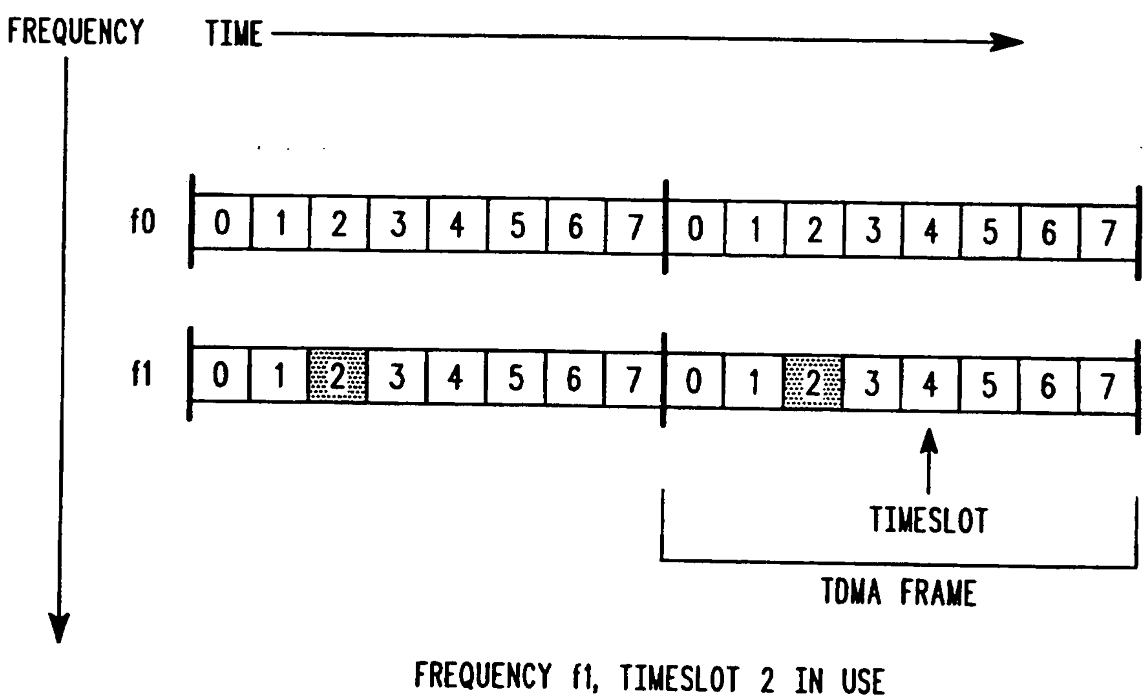
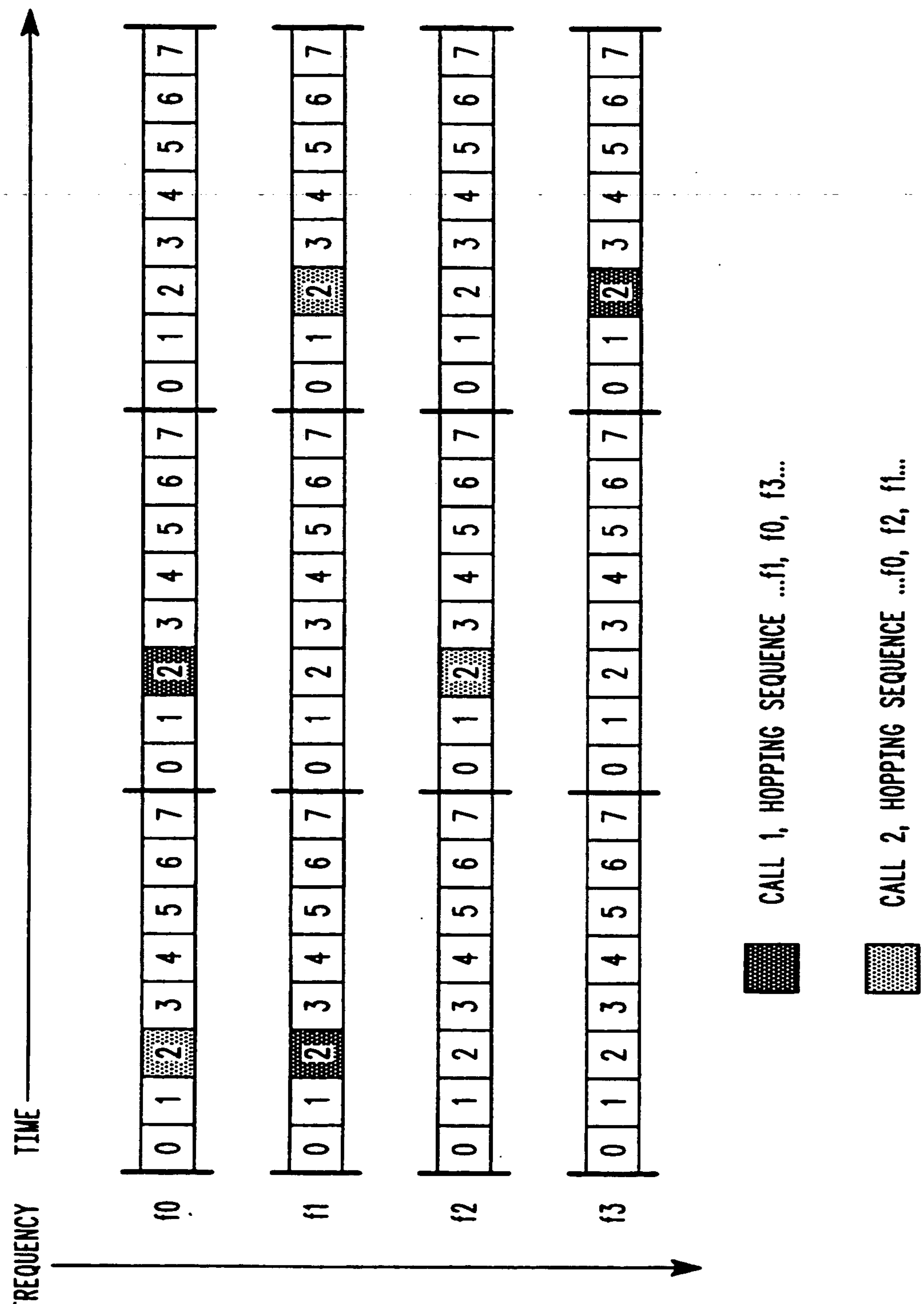

FREQUENCY
TIME
f0
0 1 2 3 4 5 6 7 0 1 2 3 4 5 6 7
f1
0 1 2 3 4 5 6 7 0 1 2 3 4 5 6 7
TIMESLOT
TDMA FRAME
FREQUENCY f1, TIMESLOT 2 IN USE

FIG.2



FREQUENCY
TIME
f0
f1
f2
f3
0 1 2 3 4 5 6 7
CALL 1, HOPPING SEQUENCE ...f1, f0, f0, f3...
CALL 2, HOPPING SEQUENCE ...f0, f2, f1...

FIG.3

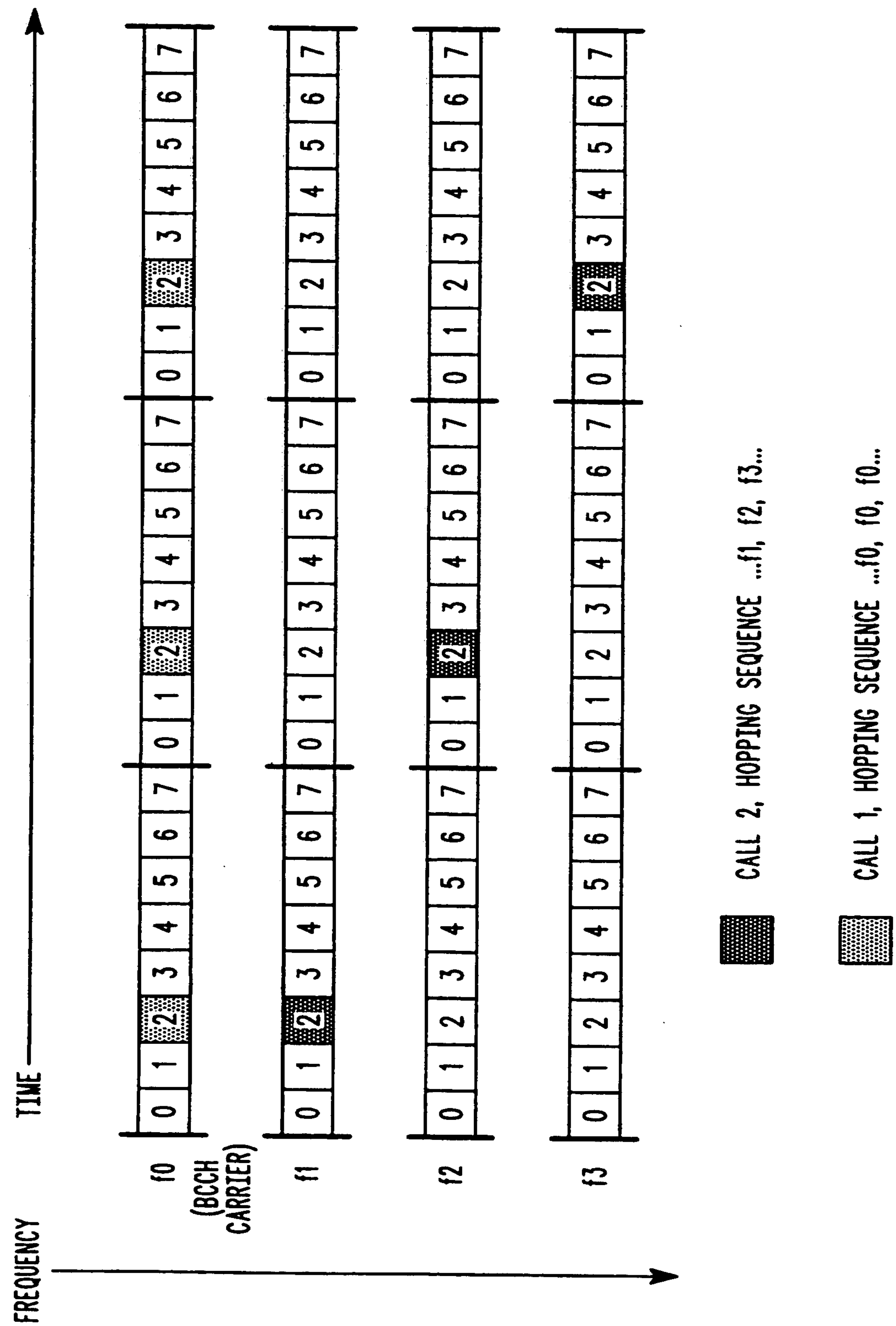

FREQUENCY
TIME
f0 (BCCH CARRIER)
f1
f2
f3
0 1 2 3 4 5 6 7
CALL 2, HOPPING SEQUENCE ...f1, f2, f3...
CALL 1, HOPPING SEQUENCE ...f0, f0, f0...

FIG.4

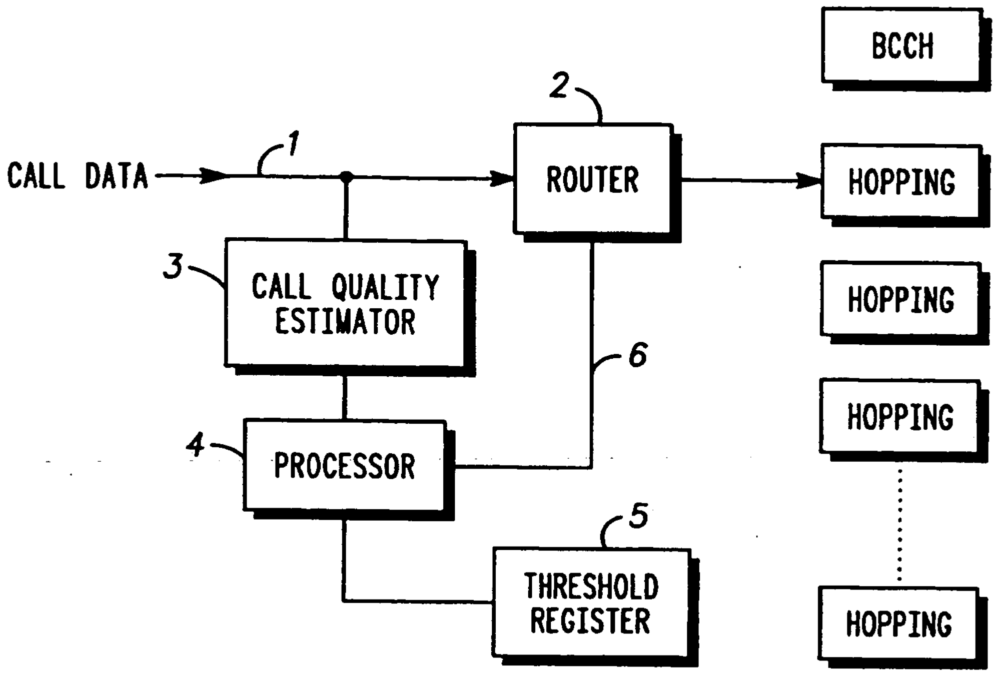

BCCH
2
1
CALL DATA
ROUTER
HOPPING
3
CALL QUALITY ESTIMATOR
HOPPING
6
HOPPING
4
PROCESSOR
5
THRESHOLD REGISTER
HOPPING

FIG.5

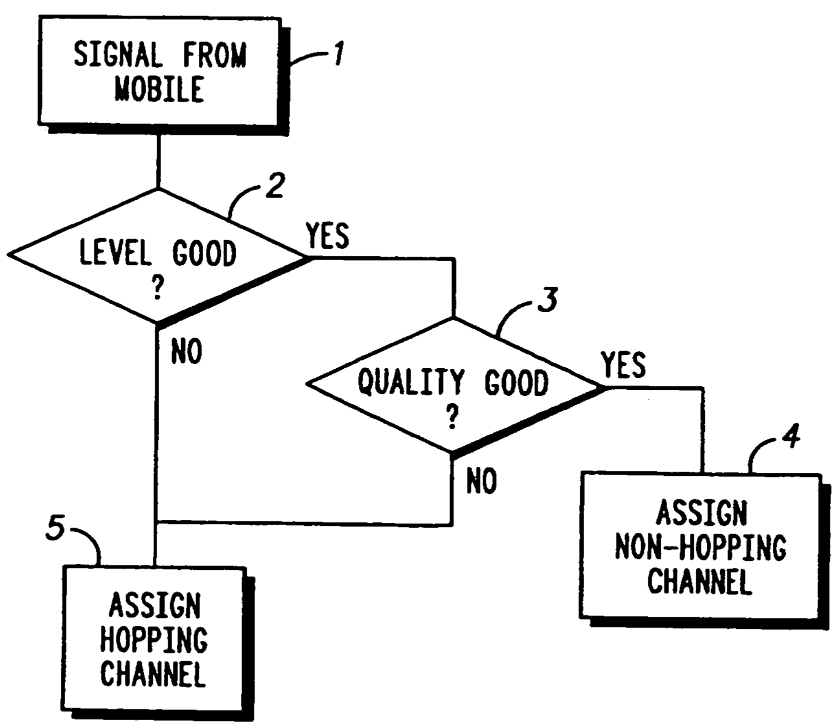
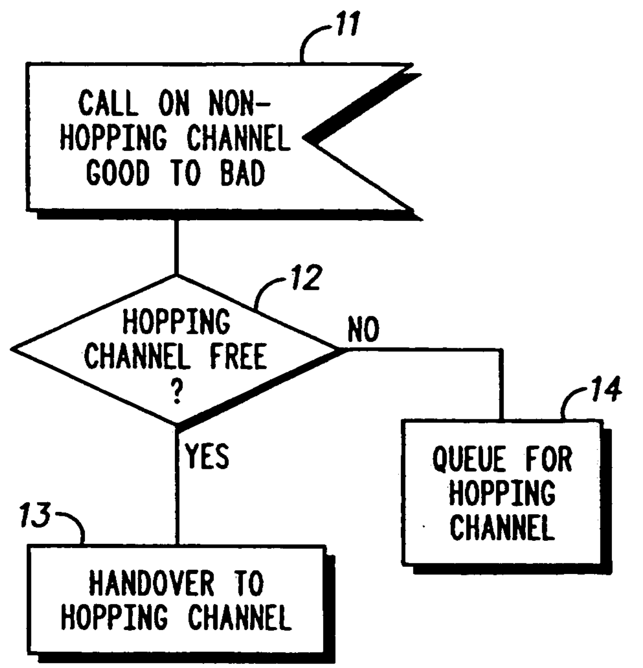
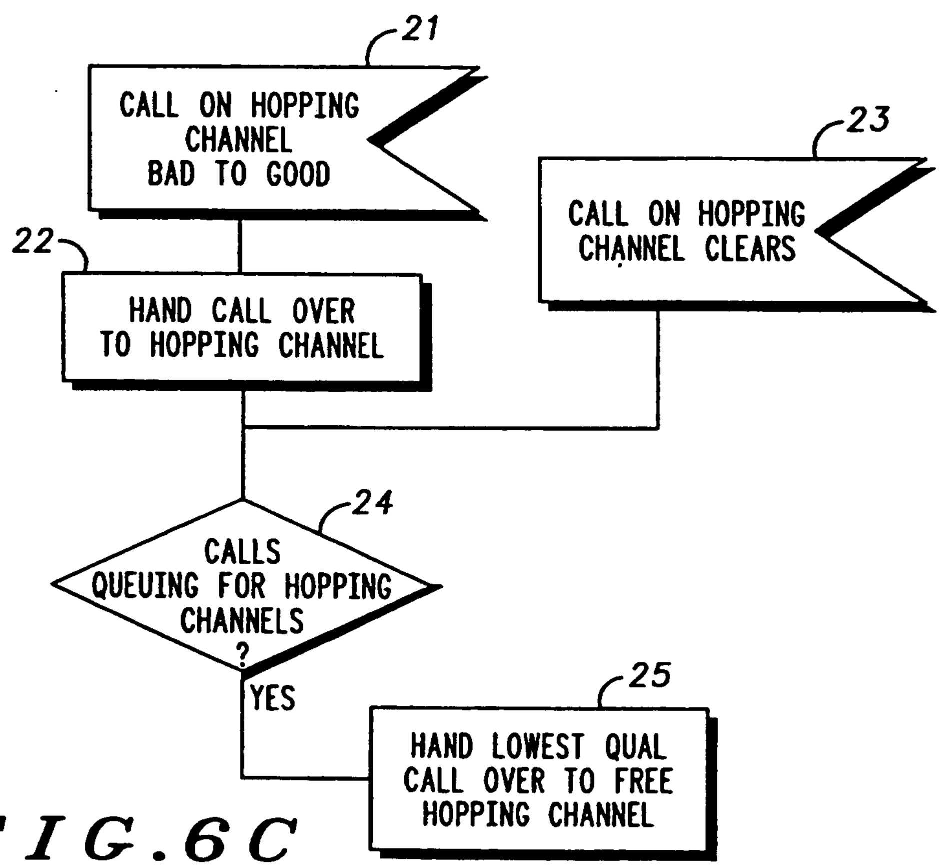

SIGNAL FROM MOBILE
1
2
LEVEL GOOD ?
YES
NO
3
QUALITY GOOD ?
YES
NO
4
ASSIGN NON-HOPPING CHANNEL
5
ASSIGN HOPPING CHANNEL

FIG.6A



11
CALL ON NON-HOPPING CHANNEL GOOD TO BAD
12
HOPPING CHANNEL FREE ?
NO
14
QUEUE FOR HOPPING CHANNEL
YES
13
HANDOVER TO HOPPING CHANNEL

FIG.6B



21
CALL ON HOPPING CHANNEL BAD TO GOOD
23
CALL ON HOPPING CHANNEL CLEARS
22
HAND CALL OVER TO HOPPING CHANNEL
24
CALLS QUEUING FOR HOPPING CHANNELS ?
YES
25
HAND LOWEST QUAL CALL OVER TO FREE HOPPING CHANNEL

FIG.6C

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CARRIER ALLOCATION SYSTEM FOR CELLULAR NETWORK

Field of the Invention

This invention relates generally to cellular radio communication networks and more particularly to the allocation of carrier frequencies to calls using such networks.

Background of the Invention

In a typical cellular radio network the area over which service is to be offered is divided into a number of smaller areas called cells, each of which is served from its own base station. Each cell has its own antenna or antennas for transmission to and reception from a user station, normally a mobile station. An important principle of such a system is that carrier frequencies may be reused by several cells, provided that the geographic separation of cells sharing the same frequency is sufficient to ensure that interference is kept within tolerable limits. Such frequency sharing is essential to ensure that the frequency spectrum available to the owner of the system is efficiently used.

The general principles governing the allocation of carrier frequencies in a typical cellular network operating under the GSM (Global System for Mobile Communications) are described in the publication entitled "European digital cellular communications system (Phase 2): Radio subsystem link control," GSM 05.08 version 4.9.0, dated 15 April 1994, by the European Telecommunications Standards Institute (ETSI).

In order to improve the efficiency of use of the available frequency spectrum still further, a number of systems employ a technique known as frequency hopping. With this technique the frequency allocated to a particular call is periodically changed. This provides a number of advantages including in particular:

a) Interference averaging - the interference from stations using the same frequency in another location is averaged out since a given station will only share a frequency with a potentially interfering station for a fraction of the time occupied by a call.

b) Stationary fading reduction - a mobile station moving around a cellular system can experience fading due to multipath propagation. Such fading is frequency selective and if frequency hopping is implemented over frequencies sufficiently far apart the average fading experienced can be substantially reduced for a given call.

A typical current system such as one operating under the GSM protocol can offer both frequency hopping or non hopping channel assignments and currently allocation of frequencies is made on the basis of availability. This allocation system, although simple, does not exploit fully the advantages offered by frequency hopping and there is accordingly a need for an improved allocation system.

Summary of the Invention

According to the invention there is provided a frequency allocation system for a cellular radio network in which both frequency hopping and non hopping channels are available, including quality monitoring means for monitoring the performance of a channel between a base station and a user station and routing means, responsive to said quality monitoring means to assign to a call between

said stations a frequency hopping channel or a non hopping channel depending on the performance so monitored.

The quality monitoring means may be adapted to monitor performance on the basis of the signal strength received from the mobile station or the quality of the signal from the mobile station as indicated for example by success metrics derived from demodulation of signals during transmission, or by a combination of these parameters.

The assignment of a carrier frequency to a call may be made at the time that the call is initiated or at a time when the quality of an existing call changes sufficiently to permit an allocation made at the time of initiation to be changed either to a frequency hopping or non hopping channel. In a typical situation where a channel of the appropriate type may not be available at a given time assignment must be made on an availability basis. However provision can be made to change assignment when the appropriate channel becomes available for example when another call is ended.

A selection system embodying the invention will typically be incorporated into a network base station transceiver.

In order that the invention may be well understood a preferred embodiment thereof will now be described with reference to the accompanying drawings.

Brief Description of the Drawings

FIG.1 illustrates in simplified form the frequency reuse pattern of a typical cellular system

FIG.2 shows the assignment of calls to time slots in a network implementing the GSM protocol.

FIG.3 illustrates the application of frequency hopping to a network such as that of FIG.2

FIG.4 illustrates the transmission of dummy information in a frequency hopping system in order to maintain continuity in the BCCH channel in a GSM network.

FIG.5 shows a frequency allocation system embodying the present invention.

FIG.6a is a flow diagram showing the procedure followed by the system of FIG.5 during the random burst phase prior to the establishment of the call.

FIGS.6b and 6c show procedures followed by the system of FIG.5 when a call is in progress.

Detailed Description of the Preferred Embodiment

Referring first to FIG.1 there is shown a simplified model of a pattern of cells in a cellular network. The cells are grouped together in sub groups called clusters two of which, cluster 1 and cluster 2, are shown in the figure. The cells in a given cluster use between them all the frequencies available to the system operator and if a particular frequency F is used in for example cell C in a cluster, it will be used by no other cell in the cluster. The cells in surrounding clusters which use frequency F are arranged to be geographically separated sufficiently from cell C to keep interference received from cell C and caused to cell C at an acceptable level.

It will be appreciated that FIG.1 represents an ideal situation. In a practical situation considerations such as terrain, the presence of obstacles and the movement of the mobile station within the area served by a cluster mean

that the possibility of interference and fading is considerably higher than the simple model suggests. In general in a fixed frequency system some calls will experience a low level of interference while others will experience substantial quality degradation. When frequency hopping is applied more calls will tend to experience an average interference level rather than extremes of high and low interference and with correct system planning this average level provides an acceptable standard of communication.

The preferred embodiment of the invention is implemented in a network which is operated in accordance with the GSM protocol referred to above. This protocol requires that each available frequency be divided into TDMA (Time Division Multiple Access) frames each containing eight timeslots, allowing eight simultaneous channels of communication per frequency. As shown in FIG.2, two frequencies f0 and f1 are assigned to a cell and communication is in progress on frequency f1, in timeslot 2.

The GSM protocol allows two modes of operation:

1. "Fixed Frequency" in which a communication is assigned to a given timeslot on a given frequency (as illustrated in FIG.2)

2. "Frequency Hopping" in which a communication is assigned to a given timeslot, but the frequency employed varies from TDMA frame to TDMA frame. The sequence of frequencies assigned to a particular communication employing frequency hopping is called the "hopping sequence" and is defined by the base station. FIG.3 illustrates two calls both in progress on timeslot 2 on a

base station where four frequencies are available and frequency hopping is taking place over these frequencies.

The GSM system requires that one frequency be designated as a broadcast channel (BCCH) frequency, timeslot 0 of which channel carries signalling data from the base station to the user stations. The remaining seven timeslots on this frequency are available for speech traffic or for further signalling if required. However the GSM specification additionally requires that the base station transmit the BCCH carrier at full power constantly to permit the mobile stations to monitor signal strength and thereby to facilitate the base station selection process. This requirement demands that even in a timeslot of the BCCH carrier on which no call is in progress, dummy information must be transmitted in order to avoid a gap in transmission on this frequency. Referring to FIG.3. if f0 is the BCCH carrier and calls 1 and 2 are the only communications in progress, then dummy information is transmitted in timeslots 1, 3 to 7 (and in timeslot 2 during TDMA frames in which the calls have hopped to another frequency).

The basic element of a GSM base station is a transceiver (TRX). The transceiver can transmit eight channels of information, corresponding to the eight timeslots of a TDMA frame. If a base station has n transceivers, then in each timeslot, n communications are possible. In order to realise the situation shown in FIG.3, two transceivers are required.

In accordance with the GSM specification, in order to implement frequency hopping over more than two frequencies in a base station with only two transceivers, one of the transceivers must be reserved for the BCCH carrier transmission and accordingly does not perform frequency hopping. Dummy information is transmitted in timeslots in

which there is no communication in progress. The other transceiver executes frequency hopping over the available frequencies. This is illustrated in FIG.4. for the example of two calls in timeslot 2. There are two basic schemes available for the implementation of frequency hopping:

a) Agile hopping

In this scheme, the transceiver includes carrier generation equipment capable of changing frequency at the rate demanded by the hopping sequence.

b) base band hopping

In this scheme a number of radio carrier equipments (RCE) are provided, one tuned to each frequency in the hopping sequence. Signals from the equipment handling the baseband information are then switched between these RCE's as required by the hopping sequence.

In either case calls are conventionally assigned on the basis of availability of the hopping or non hopping channels. Thus it can occur that calls experiencing poor quality transmission, for example because they are on the edge of a cell, will be assigned to the non hopping BCCH carrier even though their average quality would be considerably better had they been assigned to a frequency hopping channel. Equally some calls which are experiencing good quality transmission for example because they involve mobile stations very close to the serving base station will be assigned to the frequency hopping channels even though they did not require the enhancement in quality provided by such assignment.

The embodiment of the invention shown in FIG.5. provides a much improved frequency assignment mechanism by

increasing the probability that calls likely to experience good quality transmission are served by the non hopping carrier and that calls likely to experience poorer quality are served by a hopping channel.

Referring to FIG.5. the base station, following normal procedure under the GSM protocol, develops for each call in progress, a collection of call data on line 1 which contains inter alia data representing the signal strength associated with the call (RXlev) and the quality of the call as determined for example by the error level (RXqual). The call data also includes information identifying the calling station and the station with which communication is established. Conventionally the call data is used to determine the necessity and timing of handover of a call to another base station when quality deteriorates below a certain level and plays no part in the frequency allocation process in the current base station. Thus the call data is typically applied to a call router (2) which directs the call to a hopping or non hopping carrier according to availability. However in the preferred embodiment of the present invention the base station is further provided with a call quality estimator (3) which is arranged to provide the following inputs to a microprocessor (4):

1. A signal strength estimate derived from the amplitude of the digitally modulated data samples.

2. A signal quality estimate. This estimate is conveniently obtained from success metrics derived from the data demodulation process.

Associated with microprocessor (4) is a threshold register (5) which contains threshold values for signal strength and quality. Microprocessor (4) is arranged to produce control signals on a bus (6) to the router (2) which is responsive to these signals to direct the call to

a frequency hopping channel or to a non hopping channel depending on the result of a comparison made by the microprocessor between the threshold values and the input call data provided by the call quality estimator (3).

In the preferred system operating in accordance with the GSM specification the input call data is also obtained from a random access burst signal transmitted by a mobile station when first seeking access to the network to establish a call, and from signalling data exchanged between a mobile and a base station at the signalling stage in the setup of a call. At the random access stage signal strength data, corresponding to RXlev, is obtained directly from the signal bursts transmitted by the mobile station. However in order to develop a measure of signal quality at this stage analogous to the parameter RXqual the following properties of the bursts are used:

1. The access burst contains a fixed synch sequence with 41 bits. The access burst is typically detected by means of a correlator looking for this sequence. The magnitude of the output from this correlator provides a measure of the bit error rate on the access burst.

2. The access burst contains 36 bits of useful data (including coding). This data is typically processed using a Viterbi equaliser, followed by a Viterbi decoder to handle the convolutional code. The final metrics of one or both of these Viterbi processes provide measures of the bit error rate.

The microprocessor may thereby be enabled to determine the performance of a call at the following stages:

(i) At the random access stage. This is when the first burst of information is sent from the mobile to the base station to indicate its intention to set up a call.

(ii) At the signalling stage. This is when signalling information related to the call setup is being exchanged between the mobile and base station.

(iii) whilst the call is in progress.

In case (iii) in the event that a call which is assigned to a non frequency hopping channel is deemed to be bad, it can be reassigned to a frequency hopping channel and thus take advantage of the performance gain offered by frequency hopping.

FIG.6a shows the procedure followed by the system of FIG.5 at stages (i) and (ii). At step 1 a signal is received from the mobile station which is either a random access burst or signalling data. At step 2 the quality estimator determines whether the signal strength is satisfactory and if not a hopping channel is assigned to the call subject to availability. If the signal strength is satisfactory the quality estimator determines at step 3 whether the call performance is satisfactory and if so a non hopping channel is assigned subject to availability.

FIGS 6b and 6c show the procedures followed when a call is in progress, i.e. at stage (iii).

At step 11 (FIG 6b) a condition is detected indicating that a call in progress on a non hopping channel has deteriorated from good performance to bad performance. At step 12 a determination is made as to whether a hopping channel is available and handover takes place at step 13. If a channel is not available the call is queued at step 14.

The other possibility, that a call is in progress on a hopping channel the performance of which changes from bad

to good is shown at step 21 in FIG 6c. Such a call is handed over at step 22 to a non hopping channel if such a channel is available. It may also occur that a call in progress on a hopping channel clears. In both situations 21 and 23 it becomes possible to signal the availability of a hopping channel to the queue for such channels at step 24, and at step 25 the queuing call with the lowest performance is handed over to the newly freed hopping channel.

While a separate microprocessor 4 has been shown in FIG.5 as the means by which the described performance assessment procedures are performed, it will be appreciated that processing facilities already available in the base station may used to perform these procedures by including appropriate modules in their operating programmes.

Further, provision is made in a GSM network for the mobile stations themselves to perform signal strength and quality assessments on signals received from the base station and to transmit to the base station data representing such assessments to form part of the input data applied to line 1. The call quality estimator (3) and the microprocessor can be arranged to take these assessments into account in addition to the assessments made at the base station to provide a more precise overall assessment of the quality of a call to determine the appropriate routing therefor.

CLAIMS

1. A frequency allocation system for a cellular radio network of the type in which both frequency hopping and non hopping channels are available, including quality monitoring means (3) for monitoring the performance of a channel between a user station and a base station and routing means (2) responsive to said quality monitoring means to assign to a call between said stations a frequency hopping channel or a non hopping channel depending on the performance so monitored.

2. A system as claimed in Claim 1 in which said quality monitoring means is adapted to monitor performance on the basis of signal strength received from a user station.

3. A system as claimed in Claim 1 or Claim 2 in which said quality monitoring means is adapted to monitor performance on the basis of the quality of the signal from a user station as indicated by success metrics derived during demodulation of a transmission from said user station.

4. A system as claimed in any of claims 1 to 3 in which said quality monitoring means includes a processor (4) and a threshold register (5), said processor being adapted to develop control signals for said router so as to cause said router to direct a call to a hopping or non hopping channel depending on the results of a comparison between signal quality data developed by said quality monitoring means from a current or prospective call and predetermined thresholds held in said threshold register.

5. A system as claimed in any of claims 1 to 4 in which said quality monitoring means is adapted to develop

performance data from the results of demodulation of signals on a traffic or signalling channel established between said stations.

6. A system as claimed in any of claims 1 to 5 in which said quality monitoring means is adapted to develop performance data from random access burst signals transmitted by said user station on requesting access.

7. A system as claimed in any of claims 1 to 6 in which said quality monitoring means is adapted to develop performance data from measurements made by said user station on signals received from said base station.

8. A system as claimed in any preceding claim in which said router is responsive to said monitoring means to reassign a current call to a hopping or non hopping channel if the performance of said current call improves or deteriorates beyond predetermined threshold levels.

9. A system as claimed in any preceding claim in which said router is responsive to said monitoring means to reassign a current call to a hopping or non hopping channel if the performance of another current call improves or deteriorates beyond predetermined threshold levels.

10. A system as claimed in any preceding claim in which said router is responsive to said quality monitoring means to reassign a current call to a hopping or non hopping channel on the arrival of a new incoming call, depending on the relative performance of said current call and said new call.

11. A frequency allocation system for a cellular radio network substantially as described with reference to FIGS. 5, 6a and 6b of the accompanying drawings.

12. A transceiver for a cellular radio network, including a frequency allocation system as claimed in any preceding claim.

The Patent Office

15

Application No:	GB 9621017.4	**Examiner:**	Nigel Hall
Claims searched:	all	**Date of search:**	16 December 1996

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): H4L (LDSJ, LDJ)

Int Cl (Ed.6): H04Q 7/38

Other: Online: WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
X	WO 96/04722 A1 (NOKIA) See particularly p.7 lines 15-21	1 at least

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.